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MEASUREMENTS OF WAVE-LENGTHS OF THE SPARK SPECTRA OF CHROMIUM, MANGANESE, AND CALCIUM; ALSO OF THE ARC SPECTRA OF CERIUM AND THORIUM; TOGETHER WITH A STUDY OF THE POSSIBLE INFLUENCE OF VARIATIONS OF CURRENT, CAPACITY, ETC. IN THE SPARK CIRCUIT.

By

FRANK LAWRENCE COOPER.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES

OF THE JOHNS HOPKINS UNIVERSITY

IN CONFORMITY WITH THE REQUIREMENTS FOR THE

DEGREE OF DOCTOR OF PHILOSOPHY.

JUNE

1907.

133,028
President's Office

Reprinted from THE ASTROPHYSICAL JOURNAL, Vol. XXX, No 5, December, 1909

ERRORS IN WAVE-LENGTHS PUBLISHED BY COOPER IN THIS *JOURNAL*

I published in this *Journal* for June 1909 a paper entitled "Measurements of Wave-Lengths of the Spark Spectra of Chromium and Calcium: Also of the Arc Spectra of Cerium and Thorium: Together with a Study of the Possible Influence of Variations of Current, Capacity, etc., in the Spark Circuit," which gave the results of an investigation carried on in the physical laboratory of the Johns Hopkins University. Much to my regret, I have had called to my attention an error in my method of calculation, which affects some of my results. No value can be attached to the wave-lengths which I gave for cerium and thorium, or to the wave-lengths of calcium between the lines λ 2208.82 and λ 2994.960, or to the wave-lengths of chromium between the lines λ 2132.749 and λ 3875.257.

I wish to add that the wave-lengths which in my opinion are trustworthy were all calculated while I was still in residence at the Johns Hopkins University, using the well-known methods practiced in the physical laboratory of that institution. I was compelled by circumstances to leave there before completing my calculations, and the rest of my work I did elsewhere on my own responsibility. When Professor Ames gave his consent to the publication of my paper as a contribution from his laboratory, he had every reason to believe that my last calculations were made following his method, because I failed to call his attention to the fact that I had used another.

It is my intention to make a recalculation of the wave-lengths at as early a date as possible.

FRANK L. COOPER

CONTENTS.

Part I.	Page
Measurement of Spark-Spectra.	1
Introduction	1
Apparatus	2
Method of Exposure	5
Lines Used as Standards	5
Corrections	6
Table of Wave-Lengths	6
Part II.	
Measurement of Arc Spectra	50
Introduction	50
Apparatus	50
Corrections	51
Table of Wave-Lengths	52
Part III.	
Effect of Current, Capacity, Self Induction, etc. upon the Wave-Length of Spark Spectra.	102
Introduction	102
Historical Review	102

	Page
Apparatus	105
Method of Exposure	105
Results	106
Biography.	109

I. Measurement of Spark-Spectra.

Introduction.

Wave-lengths of the spark-spectra of chromium, manganese, and calcium have been made by Huggins, Thalen, Kirchhoff, Hartley, Adeney, Lockyer, and Liveing and Dewar*; but the most recent determinations are those of Exner and Haschek**, being a part of their great work on the Ultra-violet Spark Spectra of the Elements.

The last observers made all their measurements from plates taken in the first order spectrum of a 15-foot concave grating. Their method of measurement which was not entirely free from objections, was to project an enlarged image of their negatives upon a screen where it fell upon a scale of 5 mm. divisions, from which they read off the wave-lengths. Considering these two facts it is reasonable to expect greater accuracy from measurements made with a carefully constructed dividing engine and upon plates taken in the second order spectrum of a 21-foot concave grating, as was the

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*Watts: "Index of Spectra".
** Sitz. der Kais. Akad. der Wiss. in Wien 1897 et seq.

case with the wave-lengths between λ2900 and 5000 given in the following tables.

The Present Measurements.

Apparatus.

The grating employed in this work was as mentioned above, a twenty-one and a half foot concave Rowland grating with 20,000 lines to the inch, mounted as described by Professor Ames in the Philosophical Magazine, 1889, p. 369, and being in all the same instrument used by Professor Rowland in his work on the Solar Spectrum. For the purpose of comparison of Spectra, the camera carries a shutter consisting of a long brass plate, capable of revolution around a horizontal axis and having throughout its length, a horizontal opening of width equal to the thickness of the plate; so that when the shutter is in a vertical position, the photographic plate is exposed along a strip extending over the whole length of the plate and over a width equal to the thickness of the shutter. When the shutter is turned horizontal, the central strip is covered and the remainder of the plate above and below the strip is exposed. The camera box was fixed regidly upon the track by means of wedges

placed under the wheels carrying the camera box.

The spark was produced by a 110-volt alternating current of about 30 amperes with a frequency of 60 cycles per second. After being stepped up to about 1000 volts, it was passed through a transformer known as the "Rowland Coil", which raised the potential sufficiently to produce a spark of about two centimeters length. The "Rowland Coil" consists of a primary of 8 layers of 150 turns each of number 12 insulated wire, and a secondary of 98 layers of 164 turns each of number 25 copper wire. The spark terminals were pieces of the metal to be studied, turned down at the spark ends to the shape of a blunt lead pencil point. The points would wear down slightly during a long exposure, but care was taken to turn down to the proper shape before each and every exposure. They were given this shape so that the spark would keep on the slit all the time of an exposure.

The arc for comparison spectrum was produced by a 110-volt direct current of about 10 amperes.

Both the arc and spark lamps were placed (the arc nearer the slit) upon a platform which was movable upon two knife edges in a direction parallel to a line drawn through the centers of the slit

and grating respectively. Stops were placed before and behind the platform at such a distance from it, that when it was against one of them the arc was in focus, and when it was gainst the other the spark was in focus; that is, in both cases the source of light was in precisely the same place at a distance of 130 centimeters from the slit.

The light was focussed upon the slit by means of a quartz condensing lens which was never disturbed during the exposure on any one given plate, so that all exposures would have the grating illuminated as near as possible the same. The spark gap was usually 8 or 9 mm. in length and its image on the slit about 6 mm.

In the secondary circuit, there were several condensers consisting of plates of copper foil and glass surrounded with transformer oil. The capacity could be varied from 0.0036 to 0.245 microfarad.

The plates used were Seeds' Orthochromatic, Seeds' No. 27, Cramer's Isochromatic, and Wratten & Wainwright's Panchromatic, all cut 1 $\frac{1}{4}$ by 19 inches, and were developed with a hydrochinon solution according to Jewell's formula*. All measurements on plates were

*Astrophysical Journal 11, 240, 1900.

made with the dividing engine which is fully described by Humphreys in the Astrophysical Journal, 6, p. 180, and also by the method described at the same place.

Method of Exposure.

As stated before, the arc and spark lam s were on a movable platform. The spark spectrum was usually taken first; the shutter turned, and then the platform, which as independent of the mounting of the grating, was carefully slipped back on the knife-edges thus placing the arc in exactly the same position, previously occupied by the spark.

Lines Used as Standards.

The standards used were iron lines whose wave-lengths have recently been determined by Fabry and Perot, that is, for that part of the spectrum extending from λ3606.687 to λ 6494.994, which were the limits of Fabry and Perot's measurements. For the shorter wave-lengths the standards used were lines whose wave-lengths have been redetermined by Mr. L. E. Jewell, basing his measurements upon the original wave-length of Professor Rowland.

Corrections.

A calibration curve was drawn for each and every plate with wave-lengths as abscissae and the difference between readings and the arc standards as ordinates. From these curves the corrections for intermediate lines were read off.

Tables of Wave-Lengths.

In the tables, r means that the line is reversed, d that it is doubly reversed, and tr that it is reversed three times. R and V indicate that the line shades off on the red or violet side respectively. n means that the line is nebulous; and br that it is broad.

In making the estimates of relative intensities between the arc and sparklines, the iron line 4045.969 was taken as standard. This intensity is marked 30 and corresponds approximately to Kayser's mark 10.

CALCIUM.

Wave-length		Intensity Spark	Arc.		Wave-Length		Spark	Intensity Arc
2208.82	br	0			3957.035		2 r	8
2372.195		1	1	H	3968.483		500 r	300 r
2398.570		or			3973.722		1 V , r	8
2994.970		1	1		4092.86	br, n	0	2
2997.347		2	3		4094.95	br, n	1	4
2999.648		1	2		4098.53	br, n	1	4
3000.883		1	1		4132.55		00	
3006.372		0	2	g	4226.751		100 r	1000 r
3009.191		1	1		4240.428		0	2
3158.889		50 r,R	10		4283.017		20 r	50
3179.342		50r,R	15		4289.372		20 r	50
3181.276		10 R	3		4298.996		20 r	30
3487.746		1	2		4302.523		50 r	100
3602.09	br	1	G	G	4307.738		20 r	100
3624.138		2	10		4318.648		30 r	50
3631.004		3	8		4355.088	br n	1	2
3644.416		3 r	20		4425.444		20 d r	V 100
3706.161		50 R,r	10		4434.965		20 d r	100 r
3736.920		50 R,r	20		4435.687		15 d r	50
K 3933.786		1000 r	500 r		4454.874		30 r	200 r
3946.900		o r	6		4456.625		15 r	20

CALCIUM.

Wave-Length	Intensity Spark	Intensity Arc.	Wave-Length	Intensity Spark	Intensity Arc.
4456.625	5 r	8	5598.592	4 r	4
4526.979R	0	20 r	5601.288	3 r	3
4578.565	4	20	5602.766	3 r	3
4581.405	5	30	4557.459	8 r	8
4585.877	7 R		5967.566	2 r	2
4685.878	1 R	30	6102.822	9	9
4778.136	2 R	3	6122.219	10 r	10
5041.616	1	2	6161.291	4	4
5188.859	2	3	6162.178	15 r	15
5260.393	0 r	0	6163.756	3	3
5261.708	3 r	3	6166.539	4	5
5262.251	3 r	3	6169.037	6	6
5264.247	3 r	3	6169.566	6	7
5265.561	3 r	3	6439.087	8 r	8
5270.270	3 r	3	6449.826	6	6
5349.453	4 r	4	6455.214	1	2
5512.983	4 r	4	6462.578	5	5
5581.979	4 r	4	6471.669	4	5
5588.786	6 r	6	6493.785	6	6
5590.224	3 r	3	6499.661	4	4
5594.472	4 r	4	5572.711	1	1
			6717.721	5	5

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc	Wave-Length	Intensity. Spark	Arc.
2132.749	0		2235.970	1	
2133.568	0		2237.651	1	
2134.651	0		2241.430	0	
2135.490	0		2241.902	0	
2141.285	0		2243.390	0	
2144.300	0		2243.740	0	
2150.815	0		2244.213	1	
2170.777	0		2244.970	0	
2171.196	0		2247.809	0	
2183.799	0		2248.000	0	
2185.098	0		2248.408	0	
2190.695	0		2248.693	0	
2191.710	0		2249.950	0	
2198.009	0		2250.098	0	
2198.698	0		2251.617	0	
2203.325	0		2252.140	0	
2208.788	0		2256.149	0	
2211.897	0		2256.760	0	
2213.883	0		2257.550	0	
2217.591	0		2257.702	0	
2218.752	0		2257.896	0	
2219.700	0		2258.147	1	
2226.781	0		2258.250	0	
2231.900	0		2258.750	0	
2233.873	0				

CHROMIUM

Wave-Length	Intensity. Spark	Arc	Wave-Length	Intensity. Spark	Arc.
2261.829	0		2324.985	2	
2265.020	0		2330.103	0	
2273.502	1		2333.551	1	
2275.601	0		2333.970	0	
2276.560	1		2334.330	0	
2277.578	0		2334.508	0	
2284.580	1		2334.618	0	
2287.300	0		2337.817	0	
2289.309	0		2340.551	0	
2290.755	1		2344.645	0	
2295.640	1		2345.407	2	
2297.270	1		2365.290	1	1
2300.589	1		2366.891	1	1
2306.940	0		2381.586	1	
2370.278	1		2389.859	1	1
2310.101	0		2394.100	1	
2314.729	1		2397.848	1	
2314.729	1		2397.848	1	
2314.820	1		2398.600	0	1
2319.150	1		2399.745	0	1
2319.489	1		2400.318	0	
2320.200	1		2404.054 br	0	

CHROMIUM

Wave-Length	Intensity. Saprk	Arc	Wave-Length	Intensity. Spark	Arc.
2408.760	0	1	2452.792	0	
2413.725	0		2454.140	0	
2416.474	1		2454.546	1	
2419.496	0		2455.300 br	0	
2419.988	0		2456.87 br	0	
2420.200	0		2456.902	0	
2425.297	0		2459.053	0	
2425.745	0		2460.547	0	
2428.448	0		2460.950	0	
2429.749	0		2462.441	0	
2430.200	0		2465.024	0	
2433.309	1		2465.730	0	
2435.397	0		2465.870	0	
2438.550	1		2466.331	0	
2445.176	0		2466.74 br	1	
2445.649	0		2469.227	1	
2446.150	0		24.69.605	0	
2446.960	0		2470.947	0	
2449.700	1		2472.955	1	
2450.028	1		2475.026	0	
2450.447	0		2475.776	0	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc.
2477.025	0		2504.432	0	2
2477.850	0		2505.937	0	
2479.903	1	1	2506.185	0	
2483.182	1		2506.49	0	
2483.907	2		2510.346	0	1
2485.602	0		2511.310	0	
2486.418	1		2512.109	0	1
2486.757	0		2512.518	0	
2487.180	0		2513.817	2	1
2489.413	1		2515.201	2	
2489.870	0		2516.000	0	
2490.209	0		2516.717	1	2
2490.87 br	0	1	2518.410	2	2
2492.747.	1	2	2519.646	0	2
2492.990	1	2	2520.744	1	
2493.387	1		2522.79	0	
2496.52 br	0	2	2523.402	3	
2497.04 br	0		2523.746	1	
2497.983	0		2527.195	0	2
2498.945	1	1	2527.516	0	
2501.602	0		2530.057	2	

CHROMIUM

Wave-Length	Intensity Saprk	Arc	Wave-length	Intensity. Spark	Arc
2530.302	1	1	2555.647	2	
2531.097	1		2557.148	0	2
2531.938	0		2557.570	0	
2534.419	1	1	2558.500	0	
2536.900	0		2559.922	1	
2537.806	0		2560.814	0	2
2538.418	4		2561.132	0	
2539.049	0		2561.951	0	
2542.860	0		2562.603	0	
2543.229	1		2563.448	1	
2544.410	0		2563.696	2	
2545.288	0	1	2564.865	0	
2546.069	0		2566.447	0	
2246.547	0		2566.598	0	1
2547.650 br	0		2566.993	0	
254 .149	1		2567.470	0	
254 .668	1		2567.71 br	0	
2550. 127	0		2568.705	1	1
2550.416	0		2569.573	0	
2551.697	2		2570.940	0	
2552.001	0		2571.896	1	2

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity Spark	Arc.
2572.239	0	1	2596.197	1	1
2573.658	1	1	2601.978	0	
2574.286	0		2603.051 br	0	1
2575.897	0		2603.816	0	
2578.398	1	2	2604.247	0	
2579.207	0	1	2605.730	0	
2582.029	0	1	2606.169	0	
2582.350	0		2606.640	1	
2583.732	0	1	2607.729	0	
2584.206	1		2608.003	1	
2585.027	0		2608.247	0	1
2585.720	0		2608.906	0	
2587.509	1	1	2610.194	0	1
2588.105	0	1	2610.930 br	1	
2588.306	0	1	2611.103 br	0	
2589.150	0		2611.697	0	1
2589.804	1		2612.48	0	1
2590.546	0	1	2613.307	0	1
2590.865	2	3	2613.616	0	
2591.948	0		2614.715	1	
2595.664	1		2616.301	0	
			2616.548	0	

CHROMIUM

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
2618.850	0	1	2647.612	0	
2619.729	1	1	2648.240	0	
2620.625	1	1	2650.947	0	
2623.472	1	2	2652.215 br	1	
2626.146	1		2653.696	3	3
2626.885	1	1	2655.897	0	
2628.006	1		2657.710 br	0	
2631.005	2		2658.695	2	3
2632.693 br	0		2659.047	1	3
2633.746 br	0		2659.586	0	
2634.447 br	0		2659.890	0	
2635.874 br	0		2660.896	0	
2636.447	0		2661.485	2	
2637.290	0		2661.850	2	1
2637.601	0		2663.147	0	
2639.248 br	0	1	2663.585	4	3
2640.100 br	0	1	2663.800	2	1
2640.827	0		2665.798 br	1	
2641.518	0		2666.195	6	3
2641.946	0	1	2668.076	1	
2643.669	0		2668.835	5	3

CHROMIUM

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
2670.215	2		2689.908	0	
2670.406	1		2690.504	0	1
2671.953	6	3	2691.147	10	3
2672.505	1	1	2692.235	2	
2672.935	4	3	2693.615	5	
2675.396	0		2694.800	0	
2675.791	2		2696.853	1	1
2676.675	0		2697.594	3	
2677.270	2o	4	2698.015	4	1
2678.874	8	3	2698.515	3	3
2680.005	0		2698.734	2	3
2680.396	1	1	2698.940	3	1
2683.550	1		2699.496	0	
2684.227	0		2700.710	0	
2685.165	0		2701.221	1	
2685.252	0		2701.215	1	
2686.105	0		2701.788	0	
2686.490	0		2702.115	0	
2687.174	5	3	2702.670	0	1
2688.394	10	2	2703.067	0	
2689.278	2		2703.645	5	1

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity Spark	Arc
27 03.951	1	1	2724.121	3	
2704.883	0	1	2726.362	0	
2705.549	0	1	2726.583	0	5
2706.227	0		2727.317	4	1
2706.665	0	1	2728.250	0	
2708.904	4		2729.829	0	
2709.420	4		2731.989	0	5
2711.015	4		2733.690	0	
2711.306	0		2734.659	0	
2712.413	5	2	2735.828	0	
2715.750	0		2737.140	0	1
2717.096	0		2739.499	1	2
2717.587	2	1	2739.841	0	
2718.210	1		2740.172	2	1
2718.485	6		2741.165	1	2
2719.157	0		2742.120	0	2
2721 178	2		2743 7^4	6	
2720.565	1		2744.367	1	
2720.787	0		2745.043	2	
2722 825	4	2	2745.486	0	
2723.688	3		2746.263	3	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity Spark	Arc.
2747.950	0		2760.406	1	
2749.023	7	3	2760.485	1	
2749.685	1		2760.612	1	
2750.817	10	3	2760.957	0	
2751.965	10	1	2761.845	0	3
2752.490	0		2762.701	10	3
2762.903	0	3	2762.846	1	1
2753.286	0		2763.695	1	
2753.753	0		2764.096	0	
2754.000	1		2764.395	1	
2754.396	2		2765.147	0	
2755.115	0	1	2765.583	1	
2755.340	1	1	2765.700	0	
2756.384	2		2766.005	1	
2757.036	1	4	2766.624	15	4
2757.605	7	3	2767.353	0	
2758.723	0		2767.692	0	1
2759.075	3		2768.253	0	
2759.496	3	1	2768.682	3	
2759.825	2		2759.451	0	
2760.145	1		2769.983	0	6

CHROMIUM.

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
2771.405	0	1	2789.107	3	
2772.032	1		2792.256	10	
2772.477	0		2793.765	0	
2773.425	2		2795.643	1	
2774.561	2		2798.803	2	1
2776.754	1		2800.290	1	
2778.175	3	1	2800.884	10	1
2779.053	0		2803.447	0	
2780.415	4	8	2804.143	0	
2781.027	1		2808.137	1	
2781.205	1	1	2809.42 br	0	
2782.480	2		2809.714	0	
2782.697	0		2810.250 br	1	
2783.959	0		2811.000	0	
2784.450	0		2811.179	1	
2785.249	0		2811.568	0	
2785.820	7		2812.120	10	1
2786.580	2		2813.642	0	
2787.715	3		2814.353	0	
2788.003	0	1	2816.917	2	
2789.184	0		2817.665	0	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc
2818.075	0		2840.566	0	
2818.183	7	1	2842.517	0	
2822.178	4	1	2842.695	0	1
2822.527	10	2	2843.350	15 r	4
2824.687	0		2846.497	2	
2825.649	1		2846.796	1	
2826.198	0		2848.500	1	
2826.285	1		2849.456	0	
2826.550	0	1	2849.936	10	4
2828.078	0		2850.447	0	
2828.906	0		2850.740	0	
2830.635	20	1	2851.485	6	1
2832.592.	3		2852.390	0	
2833.586	0		2852.795	0	
2834.397	3		2853.346	2	
2835.707	25	4	2853.935	0	
2836.590	1		2854.271	0	
2838.000	1		2854.713	0	
2838.903	4	1	2855.141	1	
2839.237	0		2855.747	10	3
2840.137	7	1	2856 .413	0	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc
2856.856	2	1	2875.135	1	
2857.495	2	1	2876.054	4	2
2858.065	1		2876.385	2	2
2858.742	1	1	2876.754	0	
2859.020	3	3	2878.057	2	2
2861.047	4	3	2878.536	1	1
2862.685	10	3	2879.307	0	2
2865.214	3	3	2880.987	3	1
2865.455	1	1	2882.010	3	
2865.803	0		2885.418	0	
2866.025	1		2886.525	0	
2866.642	4	3	2887.105	0	2
2867.239	1	1	2887.875	1	
2867.740	4	3	2888.389	2	
2868.741	0		2899.297	2	
2870.540	4	2	2889.613	2	
2871.559	0		2889.955	1	
2871.737	0	2	2891.238	3	
2873.602	2	2	2891.527	0	1
2873.957	1	1	2891.985	1	
2874.625	0		2892.890	0	

CHROMIUM.

Wave-Length.	Intensity Spark	Arc.	Wave-Length	Intensity. Spark	Arc.
2893.075	1		2906.275	0	
2893.269	0	2	2908.417	0	
2893.625	0		2909.165	0	2
2894.378	1	2	2910.775	1	
2894.945	0		2911.008	0	2
2895.134	0		2911.275	0	2
2895.785	0		2911.813	2	
2896.520	4	1	2913.655	0	
2896.878	1	2	2913.837	0	1
2897.357	0		2915.345	1	
2897.810	2		2916.187	0	1
2898.649	4	1	2921.342	2	
2899.213	1	1	2921.932	2	1
2899.590	2		2922.606	0	
2901.147	0		2923.600	1	
2902.764	0		2923.851	2	
2903.010	0		2926.279	1	
2903.719	0		2927.203	4	
2904.088	1		2928.271.	2	
2904.837	0	1	2928.455	2	1
2905.607	0	2	2929.546	1	

CHROMIUM.

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity Spark	Arc.
2930.932	1		2953.760	3	
2932.800	1		2954.741	0	
2933.715	0		2955.240	0	
2934.055	1	1	2956.705	0	
2934.380 br	1		2957.706	0	
935.255	3	1	2959.671	0	
2937.027	1		2960.042	0	
2939.550	1		2961.832	3	1
2940.340	1		2963.570	0	
2941.065	0		2966.147	2	1
2942.070	2	1	2967.025	0	
2945.832	0		2967.730	0	3
2946.900	2	1	2968.805	0	1
2947.573	0		2969.770	0	
2949.572	1	1	2971.230	0	3
2949.885	0		2972.040	10	2
2950.201	0		2975.587	0	3
2950.781	0		2976.807	1	
2951.519	0		2979.858	10	2
2952.060	0		2980.915	0	3
2952.539	0		2984.845	0	
2953.458	2	1			

CHROMIUM.

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
2985.486	10	1	3011.569	0	
2986.106 br	1	2	3013.169	0	2
2986.579	1	3	3013.840	1	3
2986.929.	0		3014.900	0	3
2988.159	1		3015.049	0	2
2988.733	0	3	3015.300	0	2
2989.263	10	1	3015.620	2	
2992.010	0	2	3017.691	1	2
2992.549	1		3018.601	0	2
2992.645	0		3018.919	0	2
2994.177	0	2	3020.826	0	2
2994.840	1		3021.676	1	3
2995.212	0	2	3024.465	1	3
2996.689	1	2	3026.755	7	
2998.916	0	2	3028.180	2	
2999.426	0		3029.261	0	2
3000.150	0		3030.356	1	2
3001.103	0	2	3031.454	0	1
3004.045	1		3033.034	1	
3005.160	1	2	3034.304	0	2
3010 .735	0		3034.634	0	

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc	Wave-Length.	Intensity. Spark	Arc.
3035.100	0		3058.445	0	
30 37.160	0	2	3059.640	1	0
3038.170	0		3061.772	0	0
3039.883	0	1	3063.460	0	
3040.350	0		3063.965	0	
3040.950	10	3	3065.201	0	1
3041.910	4		3067.291	1	
3042.945	0		3071.712	0	
3044.060	0		3072.570	0	
3044.385	0		3073.354	0	
3047.790	0	0	3073.784	0	1
3047.915	0		3077.370	1	
3050.270	10	0	3077.942	1	1
3050.830	0		3079.490	0	
3051.680	0		3083.790	0	
3052.331	0	0	3084.682	0	
3053.826	0		3085.521	0	
3053.988	1	5	3088.200	1	
3055.526.	0		3093.615	2	
3056.778 br	0		3094.120	0	
3057.956	0		3095.065	0	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc.
3095.585	0		3125.109	20	3
3096.209	2	1	3125.579	0	1
3096.228	0		3128.819	4	2
3103.560	1		3130.687	0	
3107.658	2		3132.169	20	4
3108.749	1		3134.420	2	
3109.439	0	1	3135.429	2	
3111.o10	0	1	3135.652	2	
3112.030	0		3136.822	4	2
3113.725	0		3137.252	0	
3115.265	1		3137.620	0	
3115.730	1		3138.321	0	
3116.811	1		3140.041	0	
3117.351	0		3140.330	4	
3118.290	0		3142.860	0	
3118.764	10	3	3143.050	0	
3120.481	15	3	3145.230	1	
3121.151	0		3145.880	1	
3121.312	0		3147.350	4	2
3121.945	0		3148.550	0	2
3122.705	2		3149.935	1	

CHROMIUM

Wave-Length	Intensity Spark	Intensity Arc	Wave-Length	Intensity Spark	Intensity Arc
3150.221	1		3186.680	0	
3152.320	2	1	3188.145	0	0
3154.205	0		3190.005	0	
3155.245	0		3194.112 br	0	
3158.145	1		3194.785	0	
3159.046	0	0	3197.225	5	3
3159.225	0		3198.153	0	0
3160.000	0	0	3200.025	0	
3160.247	0		3200.582	0	
3162.284	0		3201.425	1	
3163.796.	0	1	3202.700	0	
3164.286	0		3203.646	0	
3169.430	1		3205.215	1	
3172.260	2		3208.106	0	
3173.630	0		3208.707	1	0
3176.660	0		3209.297	10	1
3179.453 br	1	0	3211.421	0	0
3180.221	10	2	3211.571	0	
3181.531	1	0	3212.560	0	
3183.428	3		3212.965	0	
3184.470	0		3216.610	2	

CHROMIUM

Wave-Length	Intensity		Wave-Length	Intensity.	
	Spark	Arc		Spark	Arc.
3217.505	7	2	3257.944	0	1
3219.221	1		3258.905	1	
3219.711	0	0	3260.110	0	1
3219.901	0		3264.421	2	
3225.504	0		3266.440	0	0
3229.324	0	0	3268.651	0	
3229.560	0		3269.309	1	
3230.006	0		3269.950	1	
3231.759	0		3270.358	2	
3234.155	5		3271.260	0	
3237.840	0	1	3273.056	0	
3238.205	0	0	3274.141	0	
3238.635	5		3276.069	0	
3245.662	0	1	3278.931	0	
3249.260	0		3279.675	0	
3250.761	0		3283.193	1	
3250.940	0		3286.010	1	
3251.719	0	0	3286.460	0	
3252.002	0	1	3288.160	0	
3252.215	0		3291.040	0	
3253.0			3291.0		

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc.
3295.110	0		3324.491	3	
3295.623	4	0	3326.571	0	0
3296.482	0	0	3328.525	2	0
3298.902	0		3329.166	0	0
3301.384	0		3329.624	0	
3303.070	0		3333.070	0	0
3304.914	0		3335.530	0	
3307.220	7	0	3336.477	4	1
3308.351	0		3337.057	0	
3310.028	0		3338.062 Fr	0	
3310.865	3		3339.932	10	2
3312.115	2		3340.838	0	
3312.350	2		3342.110	0	
3313.269	1		3342.717	10	2
3314.240	1		3343.425	0	0
3314.775	2		3344.634	0	
3315.461	0		3346.154	0	1
3316.658	0	0	3346.860	0	1
3322.869	0		3347.970	5	1
3323.710	0		3349.135	0	0
3324.231	2	0	3349.619	1	0

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc	Wave-Length.	Intensity. Spark	Arc.
3351.745	0	0	3379.514	2	0
3352.101	0	1	3380.961	4 R	2
3353.251	2	0	3382.825	10	2
3355.285	0		3385.493	0	0
3357.542	3		3386.761	0	0
3359.649	10	2	3387.852	0	
3360.485	20	2	3388.365	0	0
3361.965	3	0	3390.920	0	1
3363.572	1		3391.578	4	1
3364.851	0		3393.160	4	0
3367.593	1	0	3393.980	3	0
3368.193	20	3	3394.432	3	2
3368.691	0		3395.731	2	
3369.202	1		3399.655	1	
3371.503	0		3402.542	3	0
3372.270	0		3403.494	15	3
3375.107	0		3405.407 br	0	
3376.426	0	0	3406.911	2o	3
3376.830	0		3410.715	0	0
3377.472	0		3411.164	0	
3378.476	4	0	3412.350	0	

CHROMIUM

Wave-Length.	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc
3415.580	0		3436.332	1	2
3419.435	0		3436.878	0	
3421.353	10	3	3436.570	0	
3421.770	0		3441.241	0	0
3422.992	20	3	3441.586	1	2
3424.779	0		3443.939	0	
3426.252	0		3444.501	0	
3427.230	0		3445.741	1	2
3427.745	0		3447.149	0	0
3428.040	0		3447.569	0	1
3430.012	0		3447.901	0	0
3430.465	0		3449.400	0	
3431.415	0	0	3450.999	0	
3431.776	0		3453.469	1	2
3432.149	0	0	3453.679	0	0
3432.480	0	0	3455.105	2	0
3433.453	4	1	3455.336	0	
3433.715	1	3	3455.738	1	1
3434.230	1	0	3457. 78	4	
3435.119	0	0	3458.249	1	0
3435.962	0	0	3459.428	2	

CHROMIUM.

Wave-Length	Intensity Spark	Arc	Wave -Length	Intensit. Spark	Arc.
3460.568	0	0	3477.320	0	0
3461.441	0		3478.291	0	
3462.869	0		3478.889	0	0
3463.720	0		3480.439	0	
3464.151	0		3481.439	1	1
3464.978	0	0	3481.695	1	1
3465.390	0	0	3482.745	1	
3465.685	0	0	3483.650	0	
3466.40	0		3484.289	2	0
3467.132	0	0	3486.636	0	0
3467.845	0	0	3488.578	0	0
3468.685	0	0	3494.677	0	
3469.736	0	0	3495.108	0	0
3470.585	0	0	3495.530	2	0
3471.650	0	0	3495.679	1	
3472.216	2		3502.445	0	0
3472.548	0	0	3503.508	0	
3473.036	0	0	3506.235	0	
3473.760	0	0	3510.686	0	0
3474.525	0	0	3512.000	3	
3475.270	2	0	3513.217	0	

CHROMIUM

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity Spark	Arc
3518.757	0		3566.454 br	1	3
3522.252	0		3569.238	0	
3523.14	0		3572.690	0	1
3527.201	0	0	3573.780	0	1
3513.572	0		3574.944	0	1
3532.980	0		3575.100	2	1
3536.615 br	0		3578.632	20 r	30 r
3539.078	0		3582.766	0	0
3547.180	0		3584.46 br	1	0
3548.86 br	0		3585.421	3	
3550.431	1	1	3585.637	2	
3552.76	1		3593.636	20 r	30 r
3554.072	0		3594.500	0	
3556.218	0		3599.535	0	0
3558.75 br	1	2	3601.806	2	2
3559.901	0	0	3602.708	0	0
3562.418	0		3603.919	10	1
3562.56	0		3605.479	20	30 r
3567.050	0		3608.547	0	0
3564.410	0		3609.650	0	1
3564.638	0		3610.216	0	1

CHROMIUM.

Wave-Length	Intensity Spark	Arc.	Wave-Length	Intensity. Spark	Arc.
3612.769	0	0	3649.137	2	2
3613.369	0	0	3649.920	0	
3613.928	0	0	3650.490	2	0
3615.795	0	1	3651.792	0	
3617.450	0	1	3654.052	1	2
3619.599	0		3656.404	1	2
3621.649	0		3658.316	0	
3626.449	0		3662.978	0	1
3631.758	9 r		3663.346	0	1
3632.979	1	2	3664.755	1	
3634.997	0		3666.110	0	0
3634.996	0		3666.761	0	1
3636.723	2	3	3668.155	0	0
3639.943	4	4	3676.457	0	0
3641.597	0	1	3677.815	1	0
3641.970	2	2	3677.965	3 h	0
3643.305	0		3679.170	0	0
3644.502	0		3681.636	0	0
3646.0000	0	0	3684.370	1	
3647.485	0		3685.535	0	1
3648.669	0	1	3686.926	1	1

CHROMIUM.

Wave-Length	Intensity Spark	Arc	Wave-Length		Intensity Spark	Arc
3687.454	2	1	3743.952		9	4
3687.690	2	1	3744.525		2	
3688.572	1	0	3747.326		2	
3689.414	0	0	3748.706	br	4	2
3689.667	0		3749.039	-	10	4
3693.128	0		3750.524	br	3	
3696.807	2		3754.652	n	8	
3698.044	9		3755.238		1	1
3711.490	1		3757.739		6	4
3713.946	15	1	3758.107		3	2
3715.164	6	1	3761.745	n	2	
3715.436	3		3763.956	n	2	
3716.481	1	1	3767.187		1	1
3723.373. n	3		3768.296		6	5
3727.332 n	5		3769.799		3	2
3730.314	2	2	3778.600		2	
3732.064	3	2	3783.752		0	
3737.590	3		3788.917		1	
3738.435 n	7	8	3789.784		1	1
3743.035	2	2	3790.317		1	1
3743.575	5	2	3790.514		2	1

CHROMIUM.

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc.
3791.448	4	2	3821.581	0	
3792.206	4	2	3823.644	0	10 r
3793.346	4	2	3825.402	0	
3793.932	4	2	3826.412	1	1
3794.669	3	1	3830.052	4	1
3797.198	4	2	3831.162	4	2
3797.757	6	2	3834.772	3	
3801.251 n	2		3836.102	6	1
3804.878	10	6	3841.282 n	1	2
3806.698	4	2	3849.012	1	1
3807.983	4	1	3849.452	0	1
3809.556	2		3849.631	1	1
3812.321	4	2	3849.982	1	
3814.072 n	4		3852.202	10	2
3814.690	4	3	3852.604 n	1	
3815.500	5	2	3853.222	2	1
3816.232	4		3854.262	1	1
3817.914	2	2	3854.862 n	2	
3818.529	4	1	3855.313	2	0
3819.645	6	1	3855.612	3	
3820.520	4	3	3856.229 n	1	0

CHROMIUM.

Wave-Length	Intensity Spark	Arc	Wave-Length	Intensity. Spark	Arc.
3857.659	1	1	3902.107	0	0
3862.583	8		3902.947	2	2
3865.662	1		3903.188	0	1
3866.575	1		3905.668	0	
3869.299	8		3907.358	0	
3870.291	6		3907.787	0	0
3871.462	1		3908.765	0	4
3872.607	1		3911.392	0	
3874.588	1		3914.417 br n	0	0
3875.257	6	1b r	3915.469	0	1
3879.186	1	1	3916.040	0	1
3881.318 n	9		3916.268	0	2
3881.711	0		3917.100	0	0
3883.327	0		3917.569	8	0
3883.635	1		3919.167	3	7
3885.221	10	3	3919.968	4	0
3886.799	1	3 R	3921.046 hr n	0	4
3890.867	1		3926.637	1	0
3891.927	4	0	3928.215	0	4
3894.022	10	2	3928.641	1	
3897.657	9	0	3936.128	1	
			3937.808	5	

CHROMIUM

Wave-Length		Intensity. Spark	Arc	Wave-Length		Intensity. Spark	Arc
3938.397		1		3979.519	n	3	0
3941.188		0		3979.795		0	0
3941.495		0	3	3981.235		7	1
3943.518		1		3983.278		10	0
3945.108		1		3983.331		4	4
3945.491		1	0	3984.145		1	2
3945.959		12	0	3989.988		1	2
3948.858		3	0	3991.192		0	4
3949.66	br n	1	0	3991.699		0	2
3951.077		0	0	3992.830		1	2
3951.775		0	0	3993.851		0	1
3952.407		10	0	3998.899		0	
3953.181		4	0	3999.677		2	0
3958.078	br n	1		4001. 454		3	1
3960.760		1	0	4002.549		4	
3963.10		Lo		4003.339		4	
3969.145	R V	30	5	4012.490		0	0
3971.261		1	1	4014.689	br n	4	0
3972.659		1	0	4016.084		0	
3976.698		4	5	4018.269		1	0
3978.665		0	1	4022.250		2	1

CHROMIUM

Wave-Length.	Intensity. Spark	Arc	Wave-Length.	Intensity. Spark	Arc.
4025.025	0	0	4060.615 n	1	0
4025.368	0	1	4064.738	0	
4026.184	3	1	4065.720	1	1
4027.096	3	1	4067.530	0	1
4029.537	2		4068.403	3	
4031.467	2	0	4070.963	3	
4033.199	1	0	4074.908 n	2	0
4037.307	1	0	4076.054	3	1
4038.058	1		4077.077	2	0
4039.102	1	2	4080.413	0	
4042.601	0	0	4081.723	0	
4043.813	1	0	4082.304 br	3	
4046.767	4	2	4084.153	1	
4049.2 n	1		4086.033	2	
4049.766	1	0	4090.327	3	
4051.315	1	0	4092.206	1	
4052.462	2		4093.073	1	
4054.337	0		4098.484	4	
4056.077	0	0	4099.122	2	0
4056.812	0	0	4099.450	1	
4058.774	2	2	4099.661	1	

CHROMIUM.

Wave-Length.	Intensity.		Wave-Length.	Intensity.	
	Spark	Arc.		Spark.	Arc.
4101.162	2		4142.178	4	
4104.862	4		4142.477	1	
4108.423	2		4145.798	10	
4109.587	4	0	4149.482	2	
4111.010 br	8		4151.116 n	3	
4113.259	2		4152.775	4	0
4120.640 br	3	0	4163.070	2	0
4123.327	4		4153.719	5	2
4121.813	1	0	4161.419	7	1
4122.156	3	0	4163.166	7	1
4123.400	6	0	4167.524	7	1
4125.450	2		4169.857	4	0
4126.521	8	0	4170.220	3	0
4126.918	2	2	4171.702	2	1
4127.058	2	0	4172.678	4	
4127.274	4	0	4174.621	4	2
4127.588	4	0	4175.344	3	0
4128.506	4	0	4175.958	3	0
4131.355	6	0	4177.838	2	
4132.398	1		4179.256	7	2
4134.038	0		4179.418	2	

CHROMIUM.

Wave-Length	Intensity. Spark	Arc	Wave-Length.	Intensity. Spark	Arc.
4184.909	1	1	4213.170	2	
4186.347	2	0	4216.366	2	2
4190.038	1	1	4217.567	0	2
4191.284	3	2	4221.584	3	2
4191.761	3		4222.737	2	2
4192.022	5	0	4224.530	2	0
4193.687	2	1	4224.857	2	
4194.857	1		4230.407	1	1
4195.331 br	2	2	4232.237	1	1
4197.241	3	2	4233.217	2	1
4198.421	3	2	4234.477	1	1
4200.112	2	2	4238.954	2	1
4203.581	2	2	4240.719	2	1
4204.209	1	1	4042.357	6	1
4204.472	3	2	4243.347	1	1
4206.909	3	1	4248.727	2	1
4208.364	2	1	4252.297	1	1
4209.371	3	2	4252.657 n	4	
4209.714	2	2	42 4.352 R V	30	50 r
4211.360	2	2	4255.506	2	1
4212.649	2	2	4256.157 br n	1	1

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc.	Wave-Length	Intensity. Spark	Arc.
4261.343	3	2	4293.560	2	2
4261.526	2	1	4295.960	4	3
4262.134	6	1	4297.048	3	2
4262.345	2	1	4297.754	3	3
4263.137	5	3	4299.736	2	2
4268.347	1	1	4299.966	1	1
4268.487	1	1	4300.716	2	2
4269.297 n	2		4301.171	2	1
4269.966	2	1	4302.791	1	
4271.086	2	2	4305.461	2	2
4273.987	2	2	4306.952 br	3	1
4274.305 R V	30	50 R	4312.471	1	1
4275.547.	10		4317.971	0	1
4276.076	1	1	4318.602	0	
4280.403	3	3	4319.640 br	3	2
4283.017 br	3		4320.681	1	1
4284.687	1	1	4321.312	1	1
4284.866	2	1	4321.681	1	1
4288.456	1	1	4323.572	2	2
4289.731 R V	30	30 R	4325.132	5	3
4291.984	2	2	4337.563	11	10

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc.	Wave-Length.	Intensity. Spark	Arc.
4336.408	2	1	4373.641	2	1
4336.808	2	1	4374.162	6	3
4339.448	8	5	4375.324	3	3
4339.713	7	4	4376.773	3	2
4340.128	3	2	4377.546	3	2
4341.091 br	2	1	4378.336	1	
4343.203	1	2	4379.776	2	1
4344.501	10	10	4381.110	2	2
4345.121	0 r	1	4384.980	10	8
4346.618	2	3	4387.494	2	3
4351.047	6	8	4391.760	2	3
4351.761	10	15	4395.42e	0	1
4353.861	2	1	4397.236	2	2
4356.761	2	1	4399.871	1	2
4357.532	2	1	4403.36e	2	
4359.515	6	8	4403.497	3	3
4363.098	4	3	4410.299	2	2
4368.231	2	1	4411.076	2	2
4369.661	0		4412.251	2	2
4371.273	10	10	4413.837	3	2
4373.246	2	3	4422.286	2	2
			4423.76e	2	1

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc.	Wave-Length.	Intensity. Spark.	Arc.
4424.293	3	3	4482.005	2	2
4425.156	2	1	4488.044	3	2
4426.517	2	1	4489.466	3	2
4429.966	2	1	4491.659	1	
4430.486	2	1	4491.842	2	1
4432.166	3	2	4492.311	4	1
4433.875	1	1	4495.298	2	1
4442.266	2		4496.671	10	10
4443.706	2	1	4498.745	0	2
4456.426	5	3	4500.299	1	3
4459.351	2	1	4501.112	1	2
4462.776	2	1	4501.786	0	1
4464.756	2	1	4506.668	0	2
4464.806	2	1	4510.048	1	1
4465.345	3	2	4511.911	2	1
4466.156	1	1	4514.510	0	2
4467.557	2	1	4515.338	0	1
4473.746	1	1	4521.152	0	1
4475.306	1	2	4524.846	0	1
4480.306	2 r	1	4526.115	0	1
4481.456	1		4526.480	6	8

[illegible] OMIUM.

Wave-Length.	Intensity. Spark	Arc.	Wave-Length.	Intensity. Spark	Arc.
4527.472	2	4	4564.160	1	1
4529.852	0	2	4565.518	1	
4530.698	1		4565.778	1	4
4530.742	6	8	4569.616	1	3
4532.782	0	1	4571.679	2	4
4535.142	0	2	4575.110	1	2
4535.711	5	6	4578.210	1	1
4539.778	0	3	4580.058	2	0
4540.474	0	3	4584.100	1	1
4540.712	2	3	4585.13	1	1
4541.068	1	2	4586.220	1	1
4541.522	2	1	4588.240 R	15	1
4542.517	0	2	4591.400	4	6
4543.732	0	1	4592.060 n	4	
4544.610	2	4	4592.631	-	
4545.339	0	2	4595.580	1	2
4545.961	4	8	4598.430	1	1
4553.962 n	2		4600.109	1	2
4554.972	0		4600.762	4	0
4556.138	0	3	4601.037	1	2
4556.659 V	20	1	4601.500 n	2	
4563.670	0	1			

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc	Wave-Length	Intensity. Spark	Arc
4607.171 n br	2		4646.498	2	1
4613.3 5	4	4	464 .784	0	0
4613.921	2	2	4646.119	1	1
4616.126	5	4	4649.653	0	1
4616.531	1		4649.435 br	3	2 r
4618.841	6		4651.283	4	4
4619 .532	0	1	4652.165	0	0
4621.866	1	1	4654.122	6	4
4621.949	1	2	4654.734	0	0
4622.448	2 r	2 r	4656.189	0	1
4625.917	0	1	4661.752 n	0	
4626.179	5	4	4663.314	0	1
4626.458 br n	5		4663.830	1	2
4632.141	6		4664.796	2	3
4633.093	6		4665.907	1 r	2 r
4637.173	1	1	4666.218	0	1
4637.759	1	1	4666.486	2	3
4639.500	0	1	4669.335	1	1
4641.842	3		4676.261	0	0
4643.142	3		4680.469 n	0	1 r
4646.169	6	4	4689.371	2	2

CHROMIUM.

Wave-Length.	Intensity. Spark	Arc.	Wave-Length.	Intensity. Spark	Arc.
4693.956	1	1	4789.346	3	3
4695.162	0	0	4790.342	1	1
4697.061	1	1	4792.522	3	2
4698.529	4	4	4796.193	3	2
4699.640	0		4801.043 n	0	
4700.526	1	1	4803.430	0	
4705.451 n	0		4807.545	0	
4707.296	3	4	4812.330	0	
4708.027	4	4	4816.280	0	
4723.125	0	1	4824.140	6	
4724.413	0	1	4829.371	2	2
4727.168	0	1	4836.064	0	
4729.695	0	0	4849.665	4	
4730.728	2	2	4861.649	1	1
4737.371	2	2	4864.250	3	
4745.331	0		4870.816	3	2
4752.101	2	1	4876.340	3	
4756.131	4	4	4879.500	0	
4764.299	1	1	4884.640	0	0
4766.647	0	0	4885.875	1	1
4767.569	0	0	4895.952	0	0

CHROMIUM.

Wave-Length.		Intensity. Spark	Arc	Wave-Length	Intensity. Spark	Arc.
4887.203		3	2	5090.974	0	
4891.528		0	0	5110.782	0	
4901.532		0	0	5113.142	0	
4903.232		0	0	5122.133	0	
4906.774		3	2	5123.475	0	
4922.281		0	0	5139.651	1	0
4936.347		1	2	5144.6c4	0	0
4942.4[illegible]		0	1	5166.271	1	1
4954.826		1	1	5164.[illegible]7c	0	
4995.787	n	0		5191.993	1	
5001.387	br	4		5193.507	0	
5004.384	br	4		5196.451	2	
5007.307	br n	1		5200.193	0	
5010.052		0	0	5204.518	6	r
5013.291		1	0	5206.053	6	r
5021.920		1	0	5208.434		
[illegible]		0		[illegible]	1	0
[illegible]				[illegible]	0	
[illegible]				[illegible]		
[illegible]				[illegible]	0	
[illegible]				[illegible]		

Wave-Length	Intensity. Spark	Arc.
5265.725	1	0
5275.172	0	0
5275.756	2	
5276.069	0	0
5296.711	4	1
5298.294	6	1
5300.768	0	0
5328.144 n	3	0
5345.816	6	1
5348.336	5	1
5400.624	0	0
5409.793	5	1 r
5664.004 n	0	
5767.427	1	0
5790.960	2	1
6135.770	1	1
6330.107	0	1
6362.681	1	2
6597.756	0	1
6630.051	0	0
6661.010	0	0

Wave-Length	Intensity. Spark	Arc.

II. Measurement of Arc Spectra.

Introduction.

Measurements of the arc spectra of cerium and thorium have been made by Watts and Hachenbach and Konen but only over a limited range of the spectrum. Owing to the purity of some salts of these metals, which were prepared by Dr. A. C. Neish of Columbia University and described by him in an article entitled " A New Separation of Thorium from Cerium, Lanthanum and Didymium by Metanitrobenzoic Acid", it was thought advisable to measure the wave-length over a more extended region of the spectrum.

Apparatus.

The same grating was used as that employed for the spark spectra. The dividing engine to which reference has been made before, was constructed by Professor Rowland and was used in his work on the Solar Spectrum. For plates taken in the second spectrum of a 21-foot grating, the scale reads approximately to Angstrom units.

The plates used were the same as those used in the work on spark spectra.

Corrections.

In order to illuminate all lines due to impurities, the spectrum of the carbon arc was taken on each plate for comparison. They were also compared with the spectra of all elements likely to be associated with the substance under examination. This comparison was made by direct superposition of the plates. The lines like those of spark spectra were referred to the iron lines as determined by Fabry and Perot, and Jewell respectively. A calibration curve was also drawn for each plate as was done in case of the spark spectra plates.

CERIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
2651.125	0	3052.073	0
2652.572	0	3055.345	1
2660.466	0	3056.857	1
2831.047	0	3063.115	2
2854.755	0	3068.776	0
2854.987	0	3069.776	0
2874.256	0	3071.238	0
2908.525	0	3071.735	0
2956.047	0	3073.025	0
2964.921	0	3077.470	0
2972.812	0	3079.752	0
2974.706	0	3080.049	0
2977.024	0	3083.789	0
2977.565	0	3084.568	0
2991.003	0	3090.503	0
2995.763	0	3091.431	0
3002.247	0	3096.641	0
3002.863	0	3097.041	0
3003.655	0	3103.501	1
3008.079	1	3107.378	0
3037.849	0	3109.069	0

CERIUM

Wave-Length	Intensity.	Wave-Length.	Intensity.
3110.403	0	3167.415	0
3111.318	0	3169.314	1
3127.612	0	3171.758	1
3130.441	0	3172.458	0
3130.981	1	3176.931	0
3132.725	0	3177.258	0
3133.461	0	3178.687	0
3136.842	0	3181.005	0
3137.731	0	3183.647	1
3142.399	0	3184.346	0
3144.708	0	3186.231	1
3145.387	1	3187.776	0
3146.515	1	3188.899	1
3148.585	0	3189.751	0
3149.510	0	3190.497	1
3151.265	0	3194.936	2
3154.618	0	3196.051	0
3159.882	1	3199.407	0
3164.383.	1	3201.243	1
3166.387	0	3201.836	2
3166.741	0	3203.045	0

CERIUM.

Wave-Length	Intensity.	Wave-Length	Intensity.
3206.071	0	3232.425	0
3206.603	0	3233.557	0
3207.025	0	3234.301	3
3207.728	0	3235.032	1 r
3211.061	0	3235.601	0
3212.628	0	3236.859	2
3212.707	0	3242.275	0
3216.609	0	3243.499	2
3218.499	1	3245.301	0
3219.057	3	3245.671	0
3221.042	2	3246.812	1
3221.327	2	3249.292	0
3222.547	0	3249.555	0
3223.532	0	3252.649	1
3224.057	0	3254.178	1
3225.831	0	3256.502	0
3226.164	0	3259.013	0
3227.249	2	3259.965	0
3229.251	0	3261.115	0
3229.467	1	3263.543	0
3231.391	1	3264.033	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3265.594	0	3288.365	0
3270.276	0	3290.503	0
3271.286	0	3290.729	0
3271.672	0	3293.751	0
3272.135	0	3295.078	0
3272.369	2	3295.440	1
3272.847	0	3296.337	0
3275.001	1	3297.040	0
3276.351	0	3298.475	0
3279.135	0	3300.141	0
3279.981	1	3300.269	0
3280.647	0	3303.365	0
3281.221	0	3304.972	1
3283.491	0	3306.773	0
3283.840	0	3307.365	0
3284.356	0	3308.165	1
3285.349	1	3309.298	0
3286.163	0	3311.031	0
3286.501	0	3311.627	0
3287.537	0	3312.353	0
3288.287	0	3313.439	0

CERIUM.

Wave-Length	Intensity.	Wave-Length.	Intensity.
3314.175	0	3334.045	0
3314.863	1	334.429	0
3315.338	0	3334.605	1
3317.935	0	3336.498	0
3319.002	0	3336.678	0
3320.499	0	3339.659	0
3321.087	0	3339.947	0
3323.456	0	3341.049	0
3325.498	0	3342.043	1
3326.229	0	3344.005	1
3327.405	0	3344.909	1
3327.612	0	3345.551	0
3328.069	0	3346.648	0
3329.139	0	3348.309	0
3330.625	0	3350.105	0
3331.392	0	3331.314	0
3331.947	0	3351.668	0
3332.361	0	3352. 41	0
3332.629	0	3353.118	1
3333.197	0	3353.465	0
3333.615	0	3354.108	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
3354.465	0	3374.315	0
3355.155	1	3375.272	0
3356.549	1	3375.939	0
3357.347	1	3377.274	1
3358.569	0	3379.321	0
3359.491	0	3381.658	0
3359.802	0	3383.558	0
3360.703	2	3383.549	1
3361.946	1	3384.182	0
3364.165	0	3385.493	0
3364.493	0	3387.922	0
3364.978	0	3389.802	0
3365.997	0	3390.671	0
3366.708	1	3391.758	1
3368.544	0	3393.746	0
3368.872	0	3394.071	0
3368.938	0	3394.283	0
3369.352	0	3395.187	0
3371.312	1	3395.565	0
3373.647	1	3396.882	0
3373.910	1	3398.853	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3399..115	0	3425.465	0
3400.405	0	3426.065	0
3403.749	0	3426.342	2
3404.268	0	3426.703	0
3405.047	0	3426.843	0
3405.951	0	3429.997	0
3406.102	1	3430.442	0
3406.347	1	3431.002	0
3408.549	0	3431.649	0
3412.450	0	3433.247	1
3415.751	0	3433.795	0
3416.703	0	3435.346	0
3416.815	0	3436.430	0
3416.965	0	3437.455	0
3317.543	1	3437.955	0
3417.965	0	3439.947	0
3419.045	0	3441.353	1
3420.312	0	3442.513	1
3422.612	0	3443.079	0
3422.639	2	3443.652	0
3423.992	0	3446.348	0

CHROMIUM.

Wave-Length	Intensity.	Wave-Length	Intensity.
3446.846	0	3469.071	0
3448.403	0	3469.152	0
3451.750	0	3469.543	0
3453.385	0	3470.289	0
3454.594	0	3470.562	0
3454.957	0	3472.167	0
3456.835	0	3474.372	0
3456.915	0	3474.936	0
3459.998	0	3475.799	0
3460.305	0	3476.483	0
3461.513	0	3476.985	1
3461.923	0	3477.554	0
3463.360	0	3478.111	0
3463.902	1	3479.147	0
3464.319	1	3479.752	0
3464.989	0	3480.463	0
3465.102	0	3480.519	0
3466.016	0	3481.165	0
3467.108	0	3481.329	0
3467.925	0	3482.265	0
3468.255	0	3482.531	1

CERIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
3484.892	0	3501.957	0
3485.197	2	3502.603	0
3486.978	0	3503.057	0
3488.665	0	3503.195	0
3490.287	0	3506.399	0
3491.805	0	3506.895	0
3492.647	0	3507.485	0
3493.250	0	3508.108	1
3493.859	0	3508.615	0
3494.798	0	3508.848	0
3495.157	0	3509.397	0
3495.613	0	3509.888	1
3496.075	0	3510.095	0
3496.478	0	3510.387	0
3497.491	0	3510.839	0
3498.759	0	3511.754	0
3498.846	0	3513.798	0
3500.157	0	3515.913	0
3500.832	0	3517.510	2
3501.604	1	3518.156	0
3501.729	1	3518.540	0

CERIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3519.194	1	3534.571	1
3519.853	0	3535.708	0
3520.665	1	3536.647	0
3521.139	0	3536.857	0
3522.039	1	3937.293	0
3523.347	0	3537.597	0
3524.178	0	3538.935	0
3526.815	1	3539.235	2
3527.743	0	3540.963	0
3527.975	0	3541.821	0
3528.168	0	3542.072	0
3529.759	0	3543.447	0
3529.161	0	3543.682	0
3530.160	1	3545.746	1
3530.749	0	3545.978	1
3531.059	0	3546.325	1
3531.749	0	3546.796	0
3532.750	0	3547.110	1
3533.029	0	3547.955	0
3533.759	0	[illegible]	0
3534.202	2	3548.976	0

CHROMIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3551.603	0	3573.646	0
3551.853	1	3576.349	1
3552.249	0	3577.579	2
3552.672	1	3580.728	0
3554.760	0	3580.941	0
3555.949	0	3583.775	0
3556.497	0	3584.497	0
3557.354	0	3586.927	0
3558.665	0	3587.383	0
3559.473	0	3587.779	1
3561.002	3	3588.270	0
3561.704	0	3588.593	1
3562.238	0	3590.778	1
3563.945	0	3593.129	0
3566.204	0	3594.219	0
3568.247	0	3596.257	0
3568.487	0	3596.878	0
3569.448	0	3597.392	0
3569.975	0	3598.347	1
3571.132	0	3600.137	0
3572.546	0	3600.742	2

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3601.626	0	3628.290	0
3604.218	1	3628.636	0
3606.167	0	3629.816	0
3607.659	1	3630.164	0
3607.887	0	3630.450	0
3609.735	2	3631.232	1
3610.947	1	3632.136	0
3611.386	1	3633.414	0
3611.759	0	3636.056	0
3612.436	0	3637.534	0
3613.746	1	3637.764	0
3615.674	0	3638.018	0
3616.241	0	3638.241	0
3619.410	0	3639.466	0
3619.984	0	3640.726	0
3621.187	0	3641.157	0
3622.194	1	3642.616	0
3622.446	0	3642.827	0
3623.854	2	3643.464	0
3624.176	0	3644.336	0
3625.294	0	3645 .235	0

CHROMIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3645.451	0	3664.707	0
3646.650	1	3665.137	0
3646.869	2	3666.012	0
3647.531	0	3667.759	0
3647.764	1	3667.964	2
3649.703	0	3668.705	0
3650.137	0	3671.931	0
3650.910	1	3672.161	0
3652.114	0	3672.799	1
3652.292	0	3673.650	1
3653.111	1	3674.091	0
3653.640	1	3676.127	0
3654.908	1	3679.124	0
3655.823	2	3679.411	0
3659.230	1	3679.911	0
3659.869	0	3680.454	0
3660.037	0	3680.141	0
3660.637	1	3680.869	0
3661.711	0	3681.397	0
3662.659	0	3682.100	0
3663.699	0	3687.810	0

CHROMIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3688.665	0	3715.148	0
3689.174	0	3715.469	0
3693.457	0	3716.369	2
3693.716	0	3716.919	0
3694.918	1	3717.498	0
3695.957	0	3718.195	1
3696.097	1	3718.371	2
3697.693	0	3722.119	0
3698.128	0	3722.310	0
3698.388	0	3722.757	0
3698.659	0	3723.657	0
3699.928	0	3724.647	0
3702.818	0	3725.676	1
3705.016	1	3726.969	1
3706.659	0	3727.968	1
3702.408	0	3728.421	2
3702.648	0	3729.014	0
3709.962	3	3729.920	0
3710.714	0	3730.359	0
3713.995	0	3731.909	0
3714.801	0	3733.567	1

CIRIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3739.732	0	3759.780	0
3740.167	0	3760.426	0
3741.050	0	3760.735	0
3741.421	0	3763.006	1
3741.759	0	3763.637	0
3744.066	0	3764.136	2
3746.387	1	3765.053	1
3748.067	1	3765.906	0
3750.136	0	3766.063	0
3751.066	1	3766.533	0
3751.509	2	3765.012	0
3752.407	0	3768.283	0
3752.466	0	3768.777	1
3752.913	0	3769.075	0
3753.816	0	3769.973	0
3755.473	1	3770.816	1
3755.780	1	3771.637	1
3756.327	0	3772.686	0
3757.266	0	3773.256	0
3757.897	0	3773.483	0
3759.190	0	3776.116	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3776.630	1	3794.700	0
3777.088	0	3795.266	1
3777.665	0	3796.170	0
3779.613	0	3798.670	0
3781.120	0	3797.820	0
3781.643	2	3799.071	0
3782.527	2	3800.237	1
3783.028	0	3801.554	1
3783.523	1	3802.777	0
3786.626	3	3803.080	2
3787.181	0	3807.674	0
3787.527	0	3808.10	2
3788.166	0	3809.199	1
3788.467	0	3809.481	0
3788.763	2	3810.910	0
3790.857	0	3812.211	1
3791.700	0	3814.844	0
3792.319	1	3815.777	1
3792.592	0	3817.485	1
3793.61 0	0	3818.679	0
3793.851	0	3819.009	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3820.662	1	3843.739	0
3821.252	1	3846.559	2
3821.711	1	3849.527	0
3823.905	1	3852.110	0
3824.407	0	3852.395	1
3825.215	0	3853.164	2
3827.155	0	3854.154	2
3829.346	1	3854.275	2
3829.662	1	3855.263	2
3829.985	1	3856.335	0
3831.078	1	3856.629	0
3832.256	0	3856.964	1
3832.720	0	3857.209	0
3834.204	1	3857.591	1
3834.515	1	3857.840	0
3834.754	0	3860.392	0
3835.732	0	3860.799	0
3836.076	1	3862.428	1
3837.182	0	3865.785	0
3838.257	2	3869.092	1
3838.542	2	3869.464	1

CRIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3870.863	0	3890.511	0
3874.674	1	3890.760	0
3875.017	1	3891.005	1
3876.104	0	3891.794	0
3876.857	2	3893.246	0
3878.352	2	3893.872	0
3881.658	0	3894.325	0
3881.897	0	3895.144	2
3882.454	1	3895.460	0
3883.563	0	3896.832	2
3883.967	0	3897.419	0
3884.206	0	3898.392	2
3885.220	0	3898.692	0
3885.724	0	3898.969	1
3885.978	0	3899.300	0
3887.164	0	3900.198	0
3888.365	0	3901.310	0
3888.984	0	3901.644	0
3889.289	0	3903.350	1
3889.498	0	3903.932	0
3890.019	4	3904.199	0

CERIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3904.361	1	3916.008	0
3904.601	0	3916.912	0
3905.306	0	3917.255	1
3906.952	1	3917.639	0
3907.341	1	3918.278	3
3907.414	1	3919.812	2
3908.106	0	3921.714	2
3908.400	1	3923.146	2
3908.516	1	3924.664	1
3909.024	0	3924.505	0
3909.307	1	3927.008	0
3909.759	0	3927.405	0
3909.841	0	3927.580	0
3910.706	0	3928.743	0
3911.314	0	3929.130	0
3912.206	0	3929.997	0
3912.462	2	3930.810	0
3914.004	0	3931.097	2
3914.962	0	3931.390	1
3915.534	1	3931.844	1
3916.157	2	3932.148	1

CHROMIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3932.984	0	3949.377	2
3934.744	0	3949.790	0
3935.231	0	3950.133	0
3935.907	0	3950.812	0
3937.124	0	3951.642	0
3937.614	0	3952.205	0
3937.804	0	3952.613	0
3938.058	2	3953.647	1
3939.521	0	3954.960	2
3939.813	0	3955.372	1
3940.224	2	3955.941	0
3940.607	0	3956.012	0
3940.945	1	3956.235	3
3942.163	4	3956.698	2
3942.714	2	3957.160	0
3943.111	0	3958.860	0
3943.450	0	3958.214	1
3943.917	3	3959.870	2
3944.876	0	3959.613	1
3946.689	0	3959.846	1
3947.850	1	3960.412	0

Wave-Length	Intensity.	Wave-Length	Intensity.
3960.941	2	3979.959	0
3962.102	0	3980.936	1
3963.414	0	3981.917	0
3964.217	0	3982.216	0
3964.522	1	3982.929	2
3967.174	2	3983.109	1
3967.266	1	3984.677	2
3967.517	0	3986.158	0
3970.074	0	3986.417	0
3970.462	0	3989.447	1
3970.662	0	3990.128	1
3971.784	1	3990.459	0
3972.108	1	3990.718	0
3973.188	0	3991.236	0
3974.070	0	3992.157	0
3974.247	0	3992.297	3
3975.098	0	3992.906	1
3976.738	0	3993.188	0
3977.529	0	3993.957	2
3977.797	0	3994.405	0
3978.018	2	3995.450	0

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3996.488	0	4014.929	2
3997.485	0	4015.071	0
3997.747	0	4016.609	0
3999.278	5	4019.059	0
4000.749	0	4019.297	0
4001.087	0	4019.485	0
4001.575	2	4019.907	0
4001.776	1	4020.558	0
4002.058	0	4022.292	2
4002.967	0	4023.396	0
4003.198	0	4024.508	3
4003.789	3	4025.155	1
4004.606	0	4025.909	0
4005.655	2	4027.057	0
4007.598	1	4027.676	0
4008.677	0	4028.700	3
4009.096	0	4029.298	0
4010.186	0	4029.756	0
4011.597	0	4030.227	0
4012.195	0	4030.396	2
4012.430	5	4031.339	3

CERIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4033.809	0	4055.618	0
4037.307	0	4056.907	0
4037.696	1	4058.256	0
4038.258	1	4058.759	0
[illegible]	0	[illegible].816	0
4040.757	5	4060.499	
4041.269	0	4060.737	0
4042.146	0	4061.418	0
4042.588	4	4061.306	0
4043.459	0	4061.245	1
4045.229	2	4062.957	2
4046.246	3	4063.959	0
4047.317	1	4064.818	0
4048.358	0	4065.176	0
4049.018	0	4066.348	0
4049.506	0	4066.916	0
4050.359	0	4067.219	1
4051.419	2	4068.467	1
4052.008	1	4068.856	2
4053.516	2	4070.127	0
4055.043	2 R	4070.838	0

CHROMIUM

Wave-Length	Intensity.	Wave-length	Intensity.
4071.120	0	4085.870	2
4072.956	1	4086.418	1
4073.509	2	4087.859	1
4073.159	1	4087.590	0
4074.367	0	4088.149	0
4075.728	2	4088.676	1
4075.908	3	4089.917	0 h
4076.220	1	4089.753	0
4076.679	0	4089.646	0
4077.46.	1	4090.520	1
4078.337	1	4090.968	1
4078.557	3	4091.879	0
4079.038	0	4092.120	0
4079.319	0	4092.[illegible]49	0
4079.705	1	4093.321	0
4080.[illegible]56	1	4094.030	1
4080.560	2	4095.185	0
4081.[illegible]58	3	4095.467	0
4083.280	2	4095.[illegible]40	0
4083.535	0	4096.180	0
4083.659	0	4097.[illegible]10	1

CHROMIUM

Wave-Length.	Intensity	Wave-Length	Intensity.
4099.769	0	4117.000	1
4100.918	1	4117.299	1
4101.787	2	4117.580	1
4102.700	0	4118.156	3
4104.459	0	4119.019	1
4105.518	1	4119.247	7
4106.159	0	4120.683	2
4106.956	2	4121.604	0
4107.406	3	4123.156	1
4107.819	0	4123.523	1
4108.257	0	4123.686	3
4108.748	0	4124.140	2
4109.566	0	4125.456	0
4110.400	3	4125.757	0
4110.679	1	4126.656	0
4111.417	2	4127.350	3
4111.960	1	4127.616	1
4113.749	1	4128.106	1
4114.157	0	4128.287	2
4114.928	1	4129.160	1
4115.270	2	4130.739	2

CERIUM

Wave-Length.	Intensity.	Wave-Length	Intensity.
4131.129	1	4148.907	0
4132.358	0	4149.956	10
4132.556	0	4150.976	2
4133.640	7	4152.076	3
4135.147	2	4153.165	1
4135.996	0	4154.457	1
4136.907	1	4155.266	0
4137.489	2	4155.555	1
4137.668	3	4159.048	2
4138.107	1	4160.166	1
4138.370	1	4161.187	1
4139.459	0	4162.671	0
4139.836	0	4163.546	1
4140.516	0	4165.229	3
4140.797	1	4166.677	1
4142.430	2	4166.906	2
4142.846	1	4167.602	1
4144.529.	2	4169.816	4
4145.018	3	4172.145	0
4146.250	2	4174.287	0
4148.169	0	4175.245	0

CERIUM.

Wave-Length	Intensity.	Wave-Length	Intensity.
4176.086	0	4204.730	0
4176.715	1	4205.119	0
4179.297	1	4205.830	1
4181.116	1	4209.369	1
4185.345	2	4209.971	0
4186.578	10	4213.040	0
4187.287	2	4214.02[illegible]	2
4189.166	0	4215.499	0
4189.607	1	4217.560	2
4190.635	1	42[illegible]1.183	0
4193.064	3	4222.61[illegible]	[illegible]
4193.256	2	4223.[illegible]70	0
4193.855	1	4224.529	0
4194.697	1	4227.730	2
4196.216	[illegible]	4228.260	0
4197.216	3	4231.729	1
4197.974	1	4232.020	1
4198.643	10	4232.558	0
4201.242	2	4233.182	0
4[illegible]02.833	4	4234.171	1
4203.491	0	4234.682	0

CERIUM

Wave-Length	Intensity	Wave-Length	Intensity.
4239.681	4	4270.735	2
4241.992	0	4271.756	1
4243.894	2	4273.446	0
4243.626	0	4275.517	2
4245.917	4	4278.656	1
4246.375	0	4280.145	0
4246.687	2	4281.017	1
4248.647	3	4281.137	0
4251.866	1	4285.468	1
4253.345	2	4286.646	1
4255.754	2	4289.015	3
4256.146	1	4292.615	1
4257.106	0	4292.796	0
4259.737	0	4294.797	1
4261.154	0	4296.079	1
4263.415	1	4296.366	0
4264.386	0	4296.726	7
4267.20	1	4299.364	2
4268.297	0	4300.345	3
4269.248	0	4304.296	0
4270.136	2	4304.745	0

CHROMIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4305.147	1	4345.936	2
4306.735	3	4346.436	0
4309.736	2	4349.7[illegible]	3
4310.746	0	4352.637	2
4311.647	0	4353.406	1
4315.395	1	4359.086	0
4317.316	0	4360.186	0
4320.731	2	4360.476	0
4324.617	0	4361.677	0
4326.837	0	4364.666	3
4330.405	1	4367.998	0
4331.786	0	4367.577	0
4332.700	1	4368.236	0
4334.171	0	4369.249	0
4336.842	2	4372.428	0
4337.792	3	4373.836	2
4339.336	2	4375.936	2
4340.577	0	4380.067	0
4342.188	0	4381.799	0
4342.487	0	4382.157	0
4343.597	0	4386.306	0

CERIUM

Wave-Length	Intensity	Wave-Length	Intensity.
4386.776	5	4423.437	0
4388.000	1	4423.662	0
4390.256	0	4427.081	2
4391.666	3	4427.931	2
4393.197	0	4428.433	2
4394.769	0	4429.262	3
4396.596	0	4429.991	0
4398.786	0	4437.517	0
4399.228	2	4439.237	0
4400.536	0	4440.886	0
4400.867	0	4443.743	0
4405.487	0	4444.357	2
4407.266	0	4444.718	2
4408.849	1	4449.326	3
4410.676	2	4450.757	2
4412.036	0	4455.666	0
4413.197	0	4457.812	0
4413.807	0	4460.231	7
4416.356	1	4461.143	2
4417.758	3	4463.422	2
4419.286	0	4464.691	0

CERIUM

Wave-Length.	Intensity	Wave-Length.	Intensity.
4467.547	1	4523.100	4
4471.242	5	4527.356	4
4472.710	1	4528.469	5
4474.740	1	4532.510	1
4479.359	3	4536.897	0
4483.908	3	4538.902	1
4484.830	0	4539.070	0
4485.530	0	4539.749	3
4486.909	4	4544.966	0
4494.247	0	4548.950	1
4495.398	0	4550.336	0
4496.247	0	4551.336	1
4497.659	1	4556.620	0
4500.368	0	4560.320	3
4506.448	0	4560.996	2
4508.109	0	4562.366	7
4509.198	1	4565.279	0
4511.660	0	4565.867	2
4515.470	0	4572.296	4
4518.024	0	4572.730	0
4519.598	0	4578.790	1

CERIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4579.270	1		
4582.519	2		
4591.150	0		
4593.948	3		
4606.439	2		
4615.220	1		
4634.930	1		
4628.178	4		
4632.339	1		
4644.150	0		

THORIUM.

Wave-Length.		Intensity.	Wave-Length.	Intensity.
3503.758		0	3519.006	0
3503.909		0	3519.105	1
3504.157		0	3520.014	0
3505.653		0	3521.200	0
3507.008		0	3521.366	1
3508.270		1	3522.058	1
3509.247	br	1	3523.656	0
3510.679		0	3525.758	0
3510.887		0	3526.146	0
3511.286		0	3526.760	1
3511.760		4	3527.858	1
3512.675		0	3527.445	0
3513.368		0	3528.967	1
3513.895		1	3529.065	1
3514.656		1	3530.435	0
3515.096		0	3531.690	0
3515.347		0	3531.754	1
3516.463		0	3532.031	0
3516.668		0	3534.663	0
3516.947		0	3536.115	0
3517.135		0	3537.4	1

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3537.568	0	3549.479	1
3538.349	0	3549.726	0
3538.507	0	3549.858	0
3538.903	0	3550.419	0
3539.425	2	3550.893	0
3539.711	3	3551.538	0
3540.475	0	3552.003	0
3541.753	0	3552.878	0
3542.085	0	3553.259	1
3542.351	0	3553.538	0
3542.636	0	3555.175	2
3542.765	0	3555.837	0
3544.158	2	3556.443	0
3545.097	2	3557.603	1
3545.404	2	3559.585	2
3546.359	0	3560.109	1
3547.489	0	3561.015	0
3548.047	0	3561.928	0
3548.275	0	3563.527	0
3548.593	1	3567.186	0
3549.048	1	3567.401	1

THORIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
3567.845	0	3592.937	1
3568.115	0	3593.992	0
3569.765	0	3594.247	0
3571.723	0	3595.446	0
3572.531	3	3595.752	0
3573.382	1	3597.629	0
3573.669	0	3598.247	1
3575.443	2	3599.476	0
3576.559	0	3599.685	0
3576.682	0	3600.558	0
3579.460	1	3600.975	0
3580.371	0	3601.206	2
3582.146	1	3603.372	2
3584.286.	0	3603.518	1
3587.115	1	3603.765	0
3588.375	0	3604.208	0
3589.253	0	3604.836	0
3589.465	1	3605.602	0
3589.865	0	3607.536	0
3591.203	0	3608.730	0
3591.578	0	3609.362	0

THORIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
3609.605	3	3626.065	1
3610.207	0	3632.765	0
3610.553	0	3634.358	0
3610.947	0	3634.725	1
3612.579	1	3635.396	1
3613.025	0	3636.060	1
3613.946	0	3637.701	0
3614.142	0	3638.457	0
3615.267	2	3638.779	0
3616.834	0	3639.396	2
3617.207	3	3641.241	0
3618.525	5	3642.375	3
3619.863	0	3643.641	0
3620.521	1	3644.473	0
3621.282	2	3647.484	0
3622.476	0	3647.786	1
3622.549	0	3648.287	0
3624.138	0	3648.535	0
3624.640	0	3649.378	2
3625.095	3 h	3649.565	1
3625.790	3	3650.945	1

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3651.705	0	3671.684	0
3652.317	2	3672.445	0
3652.684	1	3672.663	0
3653.701	1	3673.447	2
3654.613	0	3673.949	1
3655.248	0	3674.203	1
3656.350	0	3675.049	0
3656.839	0	3675.287	0
3657.206	2	3675.692	2
3658.326	2	3676.815	0
3658.941	0	3677.850	0
3659.654	2	3678.163	2
3659.773	2	3678.591	0
3661.750	1	3679.275	0
3663.352	1	3679.348	2
3663.847	2	3680.623	1
3665.821	0	3681.351	0
3667.134	0	3682.038	0
3668.272	1	3682.652	0
3670.152	2	3685.057	1
3670.735	0	3687.126	1

TUNGSTEN.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3688.115	0	3700.921	0
3688.903	2	3701.153	0
3690.251	0	3703.320	0
3690.649	1	3703.366	0
3690.760	1	3703.950	0
3691.560	0	3704.192	2
3691.782	0	3705.007	0
3692.014	1	3706.151	1
3692.233	1	3706.932	1
3692.714	1	3707.147	0
3693.841	0	3707.606	0
3694.007	2	3708.907	0
3694.489	0	3711.463	2
3695.472	0	3711.769	0
3696.153	1	3712.715	0
3696.407	0	3715.734	0
3697.172	0	3715.987	0
3698.253	0	3716.703	0
3698.440	1	3717.965	0
3700.017	0	3718.275	0
3700.414	0	3718.765	0

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3719.547	2	3742.407	1
3720.404	2	3743.054	2
3721.990	3	3743.641	0
3722.302	2	3744.870	0
3723.440	0	3745.753	0
3723.798	0	3746.105	2
3724.875	0	3747.693	2
3725.553	0	3750.648	0
3726.690	2	3751.247	1
3727.306	0	3752.728	4
3727.426	0	3753.387	0
3728.049	1	3754.162	0
3730.048	1	3754.740	1
3730.532	1	3755.336	0
3730.905	0	3756.007	0
3731.565	0	3756.436	0
3734.728	0	3757.829	2
3737.645	0	3758.612	0
3738.647	1	3758.868	0
3741.001	0	3759.443	0
3741.343	4	3759.551	1

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3760.440	0	3783.175	1
3761.235	0	3783.447	2
3761.647	0	3785.486	0
3762.473	1	3785.763	3
3763.035	3	3787.021	0
3763.439	0	3788.488	0
3764.450	0	3789.255	2
3765.354	0	3790.948	1
3766.241	1	3791.443	0
3768.035	1	3792.502	0
3768.585	0	3794.379	0
3769.750	0	3794.477	0
3770.208	1	3794.850	0
3771.514	2	3796.[illegible]3	0
3772.358	0	3800.505	0
3772.803	0	3803.224	2
3773.901	2	3805.969	0
3774.348	0	3808.0[illegible]6	1
3776.425	0	3808.2[illegible]0	0
3781.1[illegible]2	0	3809.964	0
3781.513	0	3811.157	0

TITANIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3813.187	1	3887.143	0
3821.563	2	3891.205	0
3823.206	0	3891.696	1
3823.705	0	3892.455	0
3827.063	0	3893.247	1
3828.539	1	3893.568	1
3829.535	0	3894.573	1
3833.203	0	3895.054	0
3836.648	2	3895.549	1
3838.006	1	3898.614	0
3839.853	2	3900.268	0
3842.115	1	3900.716	0
3854.687	3	3901.027	1
3856.513	0	3901.259	0
3873.965	1	3901.811	0
3874.980	2	3903.252	0
3875.389	1	3904.236	1
3884.675	0	3905.237	1
3884.963	0	3906.948	0
3885.697	0	3911.136	0
3887.053	0	3911.090	0

THORIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
3912.436	0	3932.376	0
3913.157	0	3933.037	0
3913.965	0	3935.715	0
3915.365	0	3937.153	0
3916.534	0	3938.059	0
3916.679	0	3938.666	1
3917.365	0	3941.367	1
3918.136	0	3942.184	0
3918.402	0	3942.790	0
3919.621	0	3943.503	1
3919.143	0	3943.818	0
3922.350	1	3945.636	1
3922.756	1	3945.941	0
3923.939	0	3946.279	1
3925.247	0	3947.477	0
3925.338	1	3948.175	1
3926.838	0	3949.006	2 h
3927.305	0	3950.540	1
3927.561	0	3951.673	1
3929.803	2	3952.909	0
3932.155	0	3955.301	1

THORIUM

Wave-Length.	Intensity.	Wave-Length	Intensity.
3956.003	1	3982.027	1
3956.743	1	3982.239	1
3956.832	1	3984.506	0
3959.439	0	3984.899	0
3960.483	0	3987.365	0
3962.548	0	3987.654	0
3963.355	0	3988.710	1
3963.610	0	3989.979	1
3965.006	0	3990.648	0
3967.547	1	3991.903	0
3969.153	0	3992.447	0
3972.286	0	3994.701	2
3972.794	0	3996.712	1
3973.370	0	3998.015	1
3973.756	1	4000.453	0
3974.378	1	4001.237	0
3976.532	0	4001.864	0
3979.175	0	4003.248	0
3980.239	0	4003.458	1
3980.901	0	4005.202	0
3981.256	0	4005.679	0

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4006.515	0	4040.021	0
4007.163	1	4041.359	0
4008.331	1	4043.276	0
4009.175	1	4043.573	0
4011.801	1	4051.046	0
4012.620	2	4053.705	0
4019.271	4	4059.403	0
4022.233	0	4060.038	0
4025.752	0	4063.547	1
4026.259	0	4064.475	0
4027.138	0	4065.789	1
4028.785	0	4067.601	1
4029.086	1	4069.364	2
4030.137	0	4069.610	1
4030.985	0	4071.925	0
4032.085	1	4072.765	0
4032.263	1	4075.683	0
4034.407	0	4075.887	0
4035.042	0	4080.475	1
4036.175	1	4080.800	0
4036.702	1	4081.537	0

4062.29	1	4109.545	1
4063.605	0	4110.795	1
4083.178	2	4111.040	1
4085.576	0	4112.667	1
4086.673	3	4115.947	1
4088.847	1	4116.575	1
4089.278	0	4123.748	1
091.525	1	4127.606	0
4093.511	0	4131.200	0
4094.907	3	4131.618	1
4097.483	0	4132.943	1
4097.887	0	4134.269	1
4099.093	1	4140.410	1
4100.518	2	4141.808	0
4001.008	1	4142.900	2
4102.417	1	4143.312	1
4103.785 br	1	4150.187	1
4104.553	1	4152.418	1
4105.502	1	4155.525	2
4106.112	1	4156.407	0
4108.597	2	4162.665	0

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4163.732	0	4220.101	0
4164.348	0	4224.208	0
4165.187	0	4224.565	0
4165.501	0	4229.472	0
4165.870	0	4230.441	0
4167.746	0	4233.357	0
4168.729	0	4234.358	0
4170.575	0	4235.046	0
4171.463	0	4235.537	0
4171.803	0	4240.700	0
4178.087	2	4242.773	0
4179.721	1	4244.062	0
4180.011	0	4247.739	0
4181.015	0	4248.015	1
4193.078	0	4249.710	0
4202.005	1	4250.318	2
4209.003	3	4253.562	0
4216.065	0	4255.781	0
4217.247	0	4256.147	0
4218.234	0	4256.262	0
4218.572	0	4257.534	0

THORIUM.

Wave-Length.	Intensity.	Wave-Length	Intensity.
4260.425	0	4290.035	0
4261.305	0	4291.646	0
4263.402	0	4295.099	0
4264.155	0	4297.357	0
4270.351	0	4298.590	1
4271.192	0	4299.350	0
4272.910	1	4300.101	0
4273.379	3	4306.369	0
4274.018	1	4307.166	0
4274.350	0	4309.976	3
4276.018	0	4313.000	0
4276.927	1	4313.307	1
4277.340	4	4315.336	0
4278.321	0	4318.346	2
4280.610	0	4319.109	0
4281.096	2	4320.146	2
4281.446	1	4320.595	1
4282.055	3	4327.146	1
4283.546	1	4328.697	0
4284.960	0	4329.519	0
4286.219	0	4331.979	0

THORIUM

Wave-Length.	Intensity.	Wave-Length	Intensity.
4333.965	0	4361.292	0
4334.727	2	4361.746	0
4337.386	2	4365.893	0
4338.120	0	4366.936	0
4341.036	0	4369.257	0
4342.265	0	4373.625	0
4342.434	1	4374.137	0
4343.612	0	[illegible]	[illegible]
4343.991		4377.337	
4344.333	1	4378.162	0
4344.661	2	4380.926	-
4346.450		4381.890	0
4347.742		4384.686	[illegible]
4349.363 br	1	4387.077	0
4353.299	0	4391.029	10
4354.[illegible]81	0	4393.008	1
4355.300	1	4394.688	0
4357.585	0	4396.500	0
4358.310	1	4398.697	0
4358.559	0	4399.089	0
4359.313	0	4400.371	0

THORIUM

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4401.816	0	4443.075	0
4402.938	1	4447.790	1
4406.667	0	4454.507	0
4410.427	0	4456.031	0
4412.535	1	4461.162	0
4412.776	6	4465.352	2
4414.505	1	4467.811	0
4416.187	0	4472.301	0
4418.524	0	4474.090	0
4421.536	0	4480.519	0
4422.047	0	4481.642	0
4423.805	1	4485.783	1
4427.836	1	4486.101	0
4432.237	0	4486.992	0
4432.945	3	4487.487	1
4436.016	0	4488.648	2
4436.239	0	4492.225	0
4436.420	0	4493.336	1
4439.148	1	4496.307	0
4440.548	0	4498.934	0
4440.856	1	4499.966	0

THORIUM.

Wave-Length.	Intensity.	Wave-Length.	Intensity.
4505.198	0		
4510.527	2		
4512.477	0		
4513.076	0		
4524.848	0		
4531.699	0		
4532.206	0		
4533.307	1		
4534.118	0		
4535.236	0		

III. Effect of Variation of Current and Capacity Upon the Wave-Lengths of Spark -Spectra.

Introduction.

Owing to the fact that the spark is always used for comparison in all line-of-sight work, it is of importance to know whether or not the wave-lengths of spark spectra remain constant under varying external conditions of current, capacity, etc. Although considerable experimenting has been done along this line during the last few years, yet there is a diversity of opinion among observers. As the spark and arc lines did not coincide on several of the spark spectra plates, this part of the investigation was undertaken to determine whether or not this displacement was due to mechanical causes.

Historical Review.

It has been observed by Hemsalech*, Schenck** and others that when small amounts of self induction were introduced into the circuit of a spark discharge, there was at once a complete extinction

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* Comptes Rendus; 129, p. 5 1899, J. de Phys. Dec. 1899.

** Astrophysical Journal; 14, p. 116, 1901.

of all the air lines from the spark spectrum, and at the same time, a narrowing of all metallic lines. As the self induction was increased, certain others, called "short lines" disappeared while certain lines called "long lines", also present in the arc, remained visible or increased in intensity. There was also a third class which were absent in the ordinary condenser spark, being present in the arc, but which appeared on introducing self induction in the circuit. But the question with which we are particularly concerned here is the effect of self-induction, capacity and current, etc upon the wave-lengths of the lines. Exner and Haschek* in the course of their measurements of the ultra-violet spark spectrum of the elements, observed that in many instances the wave-lengths of the lines in the spark spectrum differed considerably from the wave-lengths of the corresponding lines in the arc, this difference being often as much as 0.5 of an Angstrom unit. They considered this difference as due to pressure in the spark, and with data taken from the tables of Humphreys and Mohler** they estimated the pressure in the spark to be about 25 atmospheres.

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* Sitz. der Kais. Akad. der Wiss. in Wien, 1897 et seq.

** Astrophysical Journal, 1896 and 1897.

Hascheck and Mache* then attempted to show the existance of such a pressure. A spark was produced in an air-tight vessel which was filled with air and connected to a manometer. On discharging the spark they observed a sudden rise of the manometer and interpreted it as due to a pressure in the spark; but the value thus obtained was much greater than that calculated from the difference between the wave-length of the arc and spark lines. They** also found that this effect increased to a maximum and then decreased as they increased the amount of capacity across the discharge circuit.

Eder and Valenta***, however, found no displacement whatever, in case of the lines studied by Exner and Haschek.

Kent**** repeated some of Exner and Haschek's work and observed that in case of titanium the arc and spark lines did not coincide due to capacity but that the displacement did not amount to more than 0.04 of an Angstrom unit for lines in which Exner and Haschel observed

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* Sitz. de Kais. Akad. der Weiss in Wein 1898.

**Astrophysical Journal 19, p. 351, 1899.

*** Kayser: "Handbuch der Spectroscopie", Vol. II, p. 308.

**** Astrophysical Journal, 14, 201, 1900.

as much as 0.13 of an Angstrom unit.

Middlekauff* working in this laboratory with the 21-foot grating, observed no shift in case of the spark lines of iron.

Keller** working at Bonn observed a shift but found that it was due to the manner in which the light was allowed to fall upon the slit.

The Present Investigation.

Apparatus.

The same grating was employed as that used for photographing the arc and spark spectra of the elements.

For electrodes, rods of Norway iron, and also metallic chromium, manganese, and calcium were used. These were turned down to the form of a blunt lead pencil as stated before.

Method of Exposure.

One of the greatest difficulties encountered was the mechanical shift which appeared in a greater or less degree upon nearly every

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* Astrophysical Journal; 21, 2, p. 116, 1905.

** Zeitschrift. Wiss. Phot. 4, pp. 209-231, 1906.

plate. At first this was taken to be a true shift. In order to avoid any possibility of a shift due to a jar of the camera when the shutter was turned, the shutter was detached entirely and held in place by two iron clamps which rested on the floor.

The middle of the plate was generally used for photographing the spark then the shutter was turned and the arc spectrum obtained on either side, thus making it possible to observe any shift that might occur. Plates were also taken in which the arc spectrum was on the center of the plate.

Results.

A large number of plates were taken by the method described above, and invariably it was found that no shift whatever occurred. However, in the case of a few lines which were reversed either in the arc or spark, there was an apparent shift due to an unsymmetrical reversal. This is illustrated by the following wave-lengths of some of the iron lines taken from one of the plates . In case of the first and fourth lines there was an unsymmetrical reversal of the arc lines.

λ spark	λ arc	
4271.764	4271.780 (r)	.015
4307.927	4307.927 (r)	.000
4325.785	4325.785 (r)	.000
4383.542	4383.566 (r)	.024
4404.771	4404.773 (r)	.002
4415.139	4415.139	.000

The effect of increasing the current in the primary of the induction coil was to greatly increase the intensity of the spark, but at the same time, to cause more lines to reverse. The latter was especially true in the case of calcium and manganese.

The current was varied from twelve to forty amperes this being the limit of the coil. When forty amperes current was used, almost every line in the spark spectrum of both calcium and manganese was reversed, while many were doubly reversed and a few of the manganese lines were reversed three times.

Hence the conclusions to be drawn from the present investigation are the following:

(1). In the case of a spark discharge in air, there is no change produced in the wave-length by variations in the circuit conditions except that due to unsymmetrical reversal of the lines.

(2). There is no appreciable difference in wave-length between the arc and spark lines.

In conclusion, the author takes pleasure in acknowledging his great indebtedness to Professor Ames at whose suggestion the work was undertaken, and under whose immediate supervision it was carried out. He also wishes to thank both Mr. L. F. Jewell for his interest and valuable suggestions during the progress of the work, and Dr. A. C. Neish of Columbia University who prepared and furnished the salts of cerium and thorium.

BIOGRAPHY.

Frank Lawrence Cooper was born at Owosso, Michigan April 26, 1877. After receiving his early education in the district school and the Owosso High School, he taught for one year in a district school and then entered the University of Michigan in October 1896. While there he pursued a scientific course and graduated with the degree of B. S. in June 1900. The following three years he was engaged in teaching, the first year in the Manistee, Michigan High School, and the next two years in the East Side High School at Aurora, Illinois. The year 1903-4 he spent in graduate work at the University of Michigan receiving the degree of A.M. in June 1904; during this year he was also assistant in Physics in the University. In the fall of 1904 he entered the graduate department of the Johns Hopkins University, and pursued advanced work in Physics, Physical Chemistry and Mathematics. While here he has held a Hopkins Scholarship in Physics, and has also been Research Assistant in Physics.